

CONTROL OF DISCOLORATION OF PEELED WHITE POTATOES
AND METHODS FOR ANALYSIS OF TREATING SOLUTIONS

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Suggestions are offered for a process to be used in plants. Methods are presented for the measurement of sodium bisulfite in treating solutions, including solutions that contain citric acid or other acids.

Bureau of Agricultural and Industrial Chemistry
Agricultural Research Administration
UNITED STATES DEPARTMENT OF AGRICULTURE

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Control of Discoloration of Peeled White Potatoes and Methods for Analysis of Treating Solutions

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As a commercial enterprise, the marketing of peeled and cut potatoes has expanded at a rapid pace during recent years. The labor-saving features, convenience of handling, elimination of waste, savings due to reduced inventory, and assurance of high quality with minimum purchasing effort have resulted in an increasing demand for the peeled product by restaurants and institutions that supply food service. Consequently, pre-peeling firms are operating successfully in many metropolitan areas. The perishability of product continues, however, to be a major problem.

A publication in 1949 by Olson and Treadway (4) outlined the general operations of pre-peeling. Since then many requests have come to the U. S. Department of Agriculture for further details on the preservation of color in peeled potatoes. This report contains suggestions for the development of a color preservation process and also outlines methods for the control of strength of treating solutions.

Process Development

Although many attempts have been made to find other reagents for the prevention of discoloration of peeled potato surface, sulfur dioxide (or compounds containing sulfur dioxide) remains the most generally used preservative. Sulfur dioxide or the salts of sulfurous acid have been used in solutions with or without other compounds. The auxiliary substances are generally those that alter and control the acidity of the solution.

The preservation of color of peeled and cut potatoes is accomplished by dipping the product in the chemical solution. Preservation will be prolonged as the time and concentration are increased, within moderate limits. However, excessive treatment will inevitably produce an objectionable flavor in the cooked potato. A number of factors must be considered in arriving at a suitable formula. Because these factors vary it is not possible to develop a universal formula for use throughout the industry or throughout the year in any one plant. The more important variable factors are briefly discussed below.

Raw material as a factor. Large variations in tendency to discolor, as well as in cooking quality, total solids, flavor, and other factors, exist among varieties of potatoes and within varieties as conditions of growth differ. In general, for a given variety from a given growing area, a color-preservation treatment could be used that would not require much adjustment from one lot of potatoes to another. With variations in soil conditions, irrigation, fertilizer application, and other cultural conditions, however, it is possible for tubers from the same seed stock to show appreciable quality difference even when grown in different areas very close together. Further, changes that the tubers may undergo during storage may affect their tendency to discolor. By continuous trial and error and with guidance from accumulated experience of the operator, the preservative treatment can be adjusted to conform to raw material changes and seasonal climatic differences in order to keep the amount of sulfite in the product at a safe minimum.

Processing conditions. The treatment requirements to prevent discoloration (dipping time and strength of treating solution) are modified by certain factors in the process. The discoloration of peeled raw potato depends upon the availability of oxygen to some of the chemical components of the potatoes. In the presence of oxygen one group of these components (enzymes) causes others to change from colorless to red, brown, or black. Various processing steps alter the tendency to discolor. For example, the bruising action of an abrasion peeler may cause more thorough mixing of chemical components of potatoes and increase their tendency to discolor. Prolonged and thorough washing may dilute and dissolve the chemicals so that they are less likely to cause browning.

Holding potatoes under water prevents discoloration for a considerable period by keeping oxygen from the potato surface. On the other hand, long exposure to air on trimming tables and drain racks causes the discoloration problem to be more serious.

The temperature of the product is important, since discoloration is faster at higher temperatures. This is affected by the temperature of the wash water and of the treating solution, and also by the rate of lowering product temperature by refrigeration after packaging. In steam peeling and hot lye peeling, the very high temperature destroys the activity of the enzymes on the surface of the potato. However, the entire potato is not so heated and at the border between the inactivated tissue and that which is not, there is enough heat to make the color reaction very rapid. In heat-peeled potatoes, a ring of discoloration is apt to occur unless sulfite is applied rapidly after peeling. For these reasons, the particular process used and the physical layout of the plant will in part determine the strength of preservative solution required.

Storage conditions. The type of package, temperature of storage, and anticipated length of storage are also factors that enter into the development of a treatment for a commercial pre-peeling venture. Some packages offer limited control of exposure of product to air and reduce the amount of oxygen available to effect discoloration of product.

At higher storage temperatures the preservative time or storage life will be shorter. For customers having inadequate refrigeration, more frequent deliveries or stronger treatment would be required. A customer serviced twice a week or less often would require a more stable product (that is, a product with more severe treatment) than one serviced every other day. These factors must be predetermined in a general way in order to establish a satisfactory treatment for a successful pre-peeling operation.

Development of a formula. It may be seen, then, that the possibility of a universal, optimum formula for color preservation of peeled potatoes is not feasible nor is it necessary. It is possible to present a plan, however, that can be used as a basis for preliminary work. In the establishment of a pre-peeling venture, experimental runs should be made, simulating as far as possible the actual equipment, packages, and storage conditions that are contemplated, before the commercial operations are initiated. In general,

successive trials should be made in an attempt to determine the minimum strength of solution that will provide the degree of preservation required. If the treatment is too strong, the resulting sulfite flavor may result in customer complaints and cost of reagents would be unnecessarily high. Conversely, if the treatment is too mild, preservation would be inadequate and costly replacements of product for customers would be required to maintain their good will.

The two formulas given below are to be considered as possible treatment solutions for pre-peeled potatoes. They have been found effective in color preservation of peeled potatoes in laboratory demonstrations, but, because of the qualifications mentioned above, they cannot be considered as recommended treatments for every (or any) commercial establishment. They can be used for preliminary experiments and adjusted as indicated to provide for more or less severe requirements of preservation as may be encountered.

Treatment A: Dip the peeled potatoes (whole or cut) for 30 seconds in a 1.7 percent solution of sodium bisulfite (that is, 14.4 lbs. of sodium bisulfite in 100 gal. water), drain, package, and place under refrigeration,^{1/} avoiding freezing temperatures.

Treatment B: Dip the peeled potatoes (whole or cut) for 30 seconds in a solution of 0.5 percent sodium bisulfite and 0.5 percent citric acid monohydrate (that is, 4.21 lbs. of sodium bisulfite and 4.21 lbs. of citric acid in 100 gal. of water), drain, package, and place under refrigeration,^{1/} avoiding freezing temperatures.

To strengthen the treatment, more of the chemicals are used or the dipping time is increased. If the solution is too acid in Treatment B, moisture will come to the surface of the potato and leakage may occur with prolonged storage.^{2/} This may be corrected by reducing the amount of acid used, which, in turn, would necessitate the addition of more sulfite to achieve an equivalent degree of color preservation.

Determination of Sulfite and Acid in Solutions

With use, the treating solution will gradually lose its strength (for example, by absorption of the sulfite on the product and by dilution with wash water carried into the tank). Periodic checks should be made during operations and after any substantial shut down so that the strength of solution may be readjusted by addition of reagents. With practice, an analysis for sulfite can be done in a few minutes with apparatus and solutions obtainable from most laboratory supply houses.

^{1/} Refrigeration is required to prevent microbial spoilage as well as to retard color development.

^{2/} With more acid, an increased amount of sulfur dioxide escapes from the solution and better ventilation of the processing area may be required.

The frequency of testing will vary with the character of the operations. For this reason, it would probably be advisable to consult with a professional chemist in order to establish procedures for controlling the solution strength. When the technical operations are established and a suitable strength of solution determined for normal operations, the testing and addition of reagents can be conducted by anyone trained for the job.

Method I: Procedure for sodium bisulfite. Transfer 10 ml. of the treatment solution by means of a 10-ml. pipette to a 250-ml. Erlenmeyer flask containing about 50 ml. of distilled water.^{3/} Slowly add 0.1 N iodine^{4/} solution from a 50-ml. glass-stoppered burette, with agitation of the flask, until a faint, permanent yellow color appears. Multiply the burette reading by 0.057^{5/} to obtain the percentage strength of sodium bisulfite in the solution. For example, if 30.0 ml. of iodine solution were used, $30.0 \times 0.057 = 1.7$ percent sodium bisulfite, which is the solution strength.^{6/} (Table 1 lists some of the related values.)

It should be noted that for routine operations the amount of iodine solution required can be used directly as an indication of the solution strength as long as the iodine strength and the volume of the sulfite solution analyzed are not changed. If other sulfur-dioxide-containing reagents (such as sodium sulfite, sodium metabisulfite, sulfur dioxide, or mixtures) are used, the factors for concentration of the chemical would require modification. However, the titration values reflect the sulfur dioxide content which is the active ingredient and therefore are a direct measure or relative strength of solution.

Method II: Procedure for sodium bisulfite. Fill a 50-ml. burette with the treatment solution to be analyzed and add it slowly to 50 ml. of 0.1 N iodine (measured by pipette) and about 25 ml. distilled water in a 250-ml. Erlenmeyer flask. Agitate the flask during the titration and stop when the yellow-brown color disappears. Divide 26 by the number of milliliters of solution.^{7/} For example, if 15.3 ml. of the sample are used to reduce the

^{3/} A list of apparatus and solutions required is included in an Appendix, page 8.

^{4/} The standard iodine solution should be kept in a dark bottle and stored in the dark.

^{5/} In this circular, for practical use, factors have been rounded off to two significant figures.

^{6/} The equation for the main reaction: $\text{NaHSO}_3 + \text{I}_2 + \text{H}_2\text{O} = \text{NaHSO}_4 + 2\text{HI}$. Hence, 100 ml. 0.1 N iodine will oxidize 0.5203 gm. NaHSO_3 when conversion is complete. However, since the method outlined sacrifices some accuracy for speed and simplicity, the constant of the equation ($f = 0.057$) and the values in Table 1 have been modified to reflect the average sulfite recovery (92 percent) based on a series of experimental results. The lower, but fairly constant, results are due in part to a secondary reaction: $\text{SO}_2 + 4\text{HI} = 2\text{H}_2\text{O} + 2\text{I}_2 + \text{S}$ (references 1, 3).

^{7/} One hundred milliliters of 0.1 N KI_3 solution will oxidize 0.5203 gram of NaHSO_3 .

50 ml. of 0.1 N iodine, then $26/15.3 = 1.7$ percent, which is the strength of the sodium bisulfite solution. (Table 2 lists some of the related values.)

Table 1. Determination of sodium bisulfite from volume of iodine solution used. Method I.

Iodine, 0.1 N for 10 ml. bisulfite sample, in ml.	Concentration of bisulfite, %
5	0.28
10	0.57
15	0.85
20	1.14
25	1.42
30	1.71
35	1.99

Table 2. Determination of sodium bisulfite from volume of sample equivalent to 50 ml. of 0.1 N iodine. Method II.

Sample used, in ml.	Sodium bisulfite, %
5	5.20
10	2.60
15	1.73
20	1.30
25	1.04
30	0.87
35	0.74

Method II is a little less rapid than Method I. If there is suspended matter in the solution it may be necessary to filter (a cotton-and-gauze milk-filter disk will serve) to avoid clogging the burette. However, this method is more reproducible than Method I and the values are equivalent to theoretical. The added accuracy, in most cases, is not required.

Method II can be easily adapted to establish the purity of sodium bisulfite as purchased, by making up a fresh solution of known percentage by careful weighing and determining its strength. This solution should be analyzed without delay, since a slow decomposition of sulfite may take place at room temperature.

Method III: Procedure for sodium bisulfite and citric acid in the same solution. Where sodium bisulfite and citric acid are both used in the treating solution, two titrations are made and the strength of each component is calculated. The total acidity of the solution is measured first and then the bisulfite strength is determined on the same sample. The

amount of citric acid is determined by subtracting from the total acidity the amount of acid represented by the sodium bisulfite.

Total acid: Transfer 25.0 ml. of the treating solution to a 250-ml. Erlenmeyer flask and add 4 to 5 drops of phenolphthalein indicator. While agitating the flask, slowly add 0.1 N sodium hydroxide solution from a 50-ml. burette^{8/} until the first definite pink color results.^{9/} Record the amount of alkali used and retain the flask and contents for the bisulfite determination.

Sodium bisulfite: To the sample slowly add 0.1 N iodine solution from a 50-ml. burette, with constant agitation of the flask until a faint permanent yellow color results.^{10/} The burette reading is multiplied by 0.023 to obtain the percentage of sodium bisulfite (92 percent recovery is assumed). The citric acid is calculated then by subtracting half the volume of the iodine solution used (burette reading) from the amount of sodium hydroxide required and multiplying by 0.030. Thus:
(ml. NaOH - ml. $\text{KI}_3/2$) 0.030 = percent citric acid, monohydrate.
For example, if a solution requires 27.47 ml. of 0.1 N alkali and 22.1 ml. of 0.1 N iodine solutions, then $(27.47 - 22.1/2) 0.030 = 0.5$ percent citric acid, monohydrate, and $22.1 (0.023) = 0.5$ percent sodium bisulfite.

As with Method I for determination of sulfite solution strength, the calculations presented here represent a 92 percent recovery of the components. This figure is based on an experimental study of solutions containing from 0.1 to 1.0 percent of both sodium bisulfite and citric acid, monohydrate, reagent grade. It was found that calculated acidity ranged from 91.6 to 95.1 (mean 93.3)^{11/} percent, and sodium bisulfite ranged from 89.3 to 92.8 (mean 91.5) percent of theoretical recovery. A range of this magnitude is of little significance in the control of solution strength for plant operations.

^{8/} A burette with pinchcock attachment is advisable for titrating sodium hydroxide, because the alkali will frequently cause a glass stopcock to stick.

^{9/} The alkali titration of sodium bisulfite with phenolphthalein as an indicator does not give a sharp endpoint. As an aid in identification of the pink color, one may run a blank consisting of about 50 ml. water, 4 to 5 drops of phenolphthalein, and one drop of the standard 0.1 N alkali.

^{10/} The pink color fades as iodine is added.

^{11/} The neutralization of sodium bisulfite with alkali is incomplete unless neutral hydrogen peroxide is added (reference 2).

Solutions of sodium bisulfite and other acids. In some cases edible acids other than citric may be desirable and modifications must be made in the method of measuring acid strength. Carbonic acid is sometimes used and is applied by bubbling carbon dioxide gas into the tank from a cylinder. However, the loss of this gas to the atmosphere may be excessive unless the means of addition is carefully worked out. It may be difficult to attain and maintain a concentration of carbonic acid suitable to the conditions required. The determination of carbon dioxide (reference 2) can be done by adding an excess of 0.1 N barium hydroxide and back titrating the excess with 0.1 N hydrochloric acid with phenolphthalein as an indicator.

The barium solution will absorb carbon dioxide from the atmosphere during preparation unless air is excluded. The burette assembly should be protected with a soda-lime tube. This should, in turn, be blanked off from the air with a rubber stopper when not in continuous use. The barium hydroxide should be checked occasionally with standard HCl.

When phosphoric acid is used to acidify the bisulfite solution the direct alkali titration of all three hydrogens is not complete. However, an approximation may be accomplished by using two indicators (reference 2). The first titration is made to the methyl orange end point with 0.1 N alkali. Calcium chloride is then added and the solution chilled to below 20°C. (68°F.) to precipitate calcium phosphate. The titration is then continued to the phenolphthalein end point with all three hydrogens neutralized. More accurate methods for phosphoric acid analysis are considerably slower.

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APPENDIX: Apparatus and Solutions Required

Method I: Flasks, Erlenmeyer, 250 ml., about - - - - - 10
Burette with glass stopcock, 50 ml.- - - - - 2
Burette funnel - - - - - 2
Burette cap - - - - - 2
Burette brush - - - - - 1
Burette support, porcelain base - - - - - 1
Pipette, volumetric, 10 ml. - - - - - 4
Stopcock lubricant
Iodine solution, 0.1 N (Keep iodine solution
in a dark bottle and store away from the
light. About 1 liter is a sufficient
supply.)

Method II: As for Method I but substitute four 50-ml.
pipettes for the 10-ml. size.

Method III: As for I but substitute four 25-ml. pipettes
for 10-ml. size, and add:

Burettes, for use with pinchcock, 50 ml. - - 2
Pinchcock attachments - - - - - 2
Dropping bottles, 60-100 ml. - - - - - 2
Sodium hydroxide, 0.1 N - - - - - 1 liter
Phenolphthalein; dissolve 1 gm. in 100 ml.
alcohol and add 100 ml. distilled water.